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COMET HALLEY'S COLORFUL OUTBURSTS

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ABSTRACT

Two preperihelion outbursts by Comet Halley were observed, each showing different brightness changes at 2.3, 3.6, 4.6 and 10.3μm. Neither event was observed from beginning to end. The first observation on November 8, 1985, lasted of the order of a day and was accompanied by a tail-like appendage recorded photographically. During the outburst the IR colors changed dramatically, showing no significant change at 10.3μm but showing progressively more change at shorter wavelengths over a time scale of a few hours. The second outburst measurement extended over several days (January 10-13, 1986) during which time the intensities at the four wavelengths increased by roughly the same amount. Although the outbursts were of different duration, the IR measurements suggest that the first event involved volatile ice particles that evaporated, while the second was associated with long-lived nonvolatile dust grains.

1. OBSERVATIONS

All observations were made using the 60-inch NASA/Steward telescope at Mt. Lemmon. A LHe-cooled CVF was used with a 15-arc sec aperture using conventional chopping/nodding techniques with a chopper throw of 210" N-S (Lynch *et al.* 1986). Three broadband filters were used with central wavelengths and half-power bandpasses of 2.3, 3.6, 4.6 and .5, .56, and .28μm, respectively. At 10.3μm the CVF defined the spectral band with a bandpass of 0.2μm. The standard stars used were α Tau and β Peg, although the brightness changes observed are insensitive to the adopted fluxes of these stars.

2. OUTBURSTS

Figure 1 shows the time evolution of the outburst observed on November 8, 1985, UT. At 10.3μm the flux remained steady within the measurement uncertainties, but at 3.6μm the brightness dropped from magnitude 7.6 to 8.5, and at 2.3μm the change was from 6.2 to 9.4, more than 3 magnitudes. Clearly, the diminution increased toward shorter wavelength. Between the times of the two sets of observations a photograph was taken of the comet through the 6-inch finder telescope (Lynch and Russell, 1987), showing an irregular mass extending southward (p.a. 190°) by about 1 arc minute (Fig. 2). It is not known how long the feature endured.

The November 8, 1985, outburst occurred very near the ecliptic plane when the comet was 1.82 AU from the sun and only 17° from opposition. During this time many sporadic prototails formed and disappeared, and the properties of the outburst may well have been indicative of the rupture of the crust tail formation. The evident color changes are consistent with the behavior of ejected volatile material: ices show little absorption (and thus emission) at 10μm, yet they would be expected to scatter solar radiation very efficiently at shorter wavelengths until the particles evaporated, typically with time scales of a few hours for 1μm-size particles. This ice hypothesis for the grain composition of the ejected material is supported by Bregman and Witteborn's report (1985) of a 3μm-ice feature.

Figure 1 also shows a very different type of color behavior during the much longer-lasting outburst occurring January 10-13, 1986. Here the brightness at all four wavelengths increased by roughly the same amount, about 30 percent/night. Although the expulsion mechanism is not known, the time behavior of the dust emission can be understood if the ejected particles were nonvolatile, perhaps silicate particles which were known to be present during this time (Tokunaga *et al.* 1986; Gehrz and Ney, 1986). Such particles would show roughly similar brightness changes at all four wavelengths and would not evaporate. The persistence of the event suggests that the source of material endured for many days, because the transit time through the 10,000-km radius beam is roughly six hours for particles moving at velocities observed by spacecraft (Vaisberg *et al.*, typically 450 m/sec for grains of 1μm diameter).

Another outburst event occurred from approximately April 7 to 10, 1986 (Russell *et al.* 1986), and was more like the January outburst. Although no color information was obtained for that outburst, the large/small aperture observations required particles with lifetimes greater than a day, and a source of ejecta which seemed to continue for about two days. Spectral data obtained during this outburst did show a silicate feature near 10μm.

3. CONCLUSIONS

Many outbursts occurred on comet Halley and the two discussed here show unequivocal evidence for two types of color changes during outbursts and for differentiation in particle composition or particle size distribution during outbursts. The first type discussed here is consistent with an anisotropic infusion of particles into the coma over a finite period of time, which were very efficient scatterers of shorter wavelength light but very poor emitters in the thermal IR ($\lambda > 5\mu$m). These particles must be quite volatile or traveling at larger speeds than observed by spacecraft to account for the observed factor of $\sim$20 change at 2.3μm in $\sim$6 hours.

The second type of outburst appears to be a much more steady, enduring (1 - few days) source of particles, and the particles are both longer-lived and show approximately a constant increase in emission/scattering from 2.3 to 10.3μm.

Clearly, not all outbursts are the same. It is thus very important to chronicle and analyze time variability in both new and periodic comets in order to understand the mechanisms responsible for outbursts and to assess whether the mechanisms are common to both types of comets. Time-resolved spectroscopy of molecular emissions would be an ideal complement to IR observations of dust particles, especially if programs could be undertaken employing simultaneous observations of dust and gas through apertures with the same angular size. Visible imaging observations would provide, as they did for Halley, information on jets, particle trajectories, and rotation of the nucleus.

4. ACKNOWLEDGMENTS

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5. REFERENCES

1. Bregman, J. and Witteborn, F., 1985, IAU Circ. 4149.

2. Gehrz, R. and Ney E., 1986, *Proceedings of the 20th ESLAB Symposium on the Exploration of Halley's Comet*, Heidelberg, W. Germany, 27-31 October 1986, ESA SP-250, Vol. II, 101-105.

3. Lynch, D. K., Russell, R. W., Rettig, D. A., Rice, C. J., and Young, R. M., 1986, *Proceedings of the 20th ESLAB Symposium on the Exploration of Halley's Comet*,

Heidelberg, W. Germany, 27-31 October 1986, ESA SP-250, Vol. III, 479-484.

4. Lynch D. K. and Russell, R. W., 1987, *Pub. A. S. P.*, in press.

5. Russell, R. W., Lynch, D. K., Rudy, R. J., Rossano, G. S., Hackwell, J. A. and Campins, H., 1986, *Proceedings of the 20th ESLAB Symposium on the Exploration of Halley's Comet*, Heidelberg, W. Germany, 27-31 October 1986, ESA SP-250, Vol. II, 125-128.

6. Tokunaga, A. T., Golisch, W. F., Griep, D. M., Kaminski, C. D., and Hanner, M. S., 1986, *Astron. J.*, **92**, 1183-1190.

7. Vaisberg, O. L., Smirnov, V. N., Gorn, L. S., Iovlev, M. V., Balikchin, M. A., Klimor, S. I., Savin, S. P., Shapiro, V. D., and Shevchenko, V. I., 1986, *Nature*, **321**, 274.

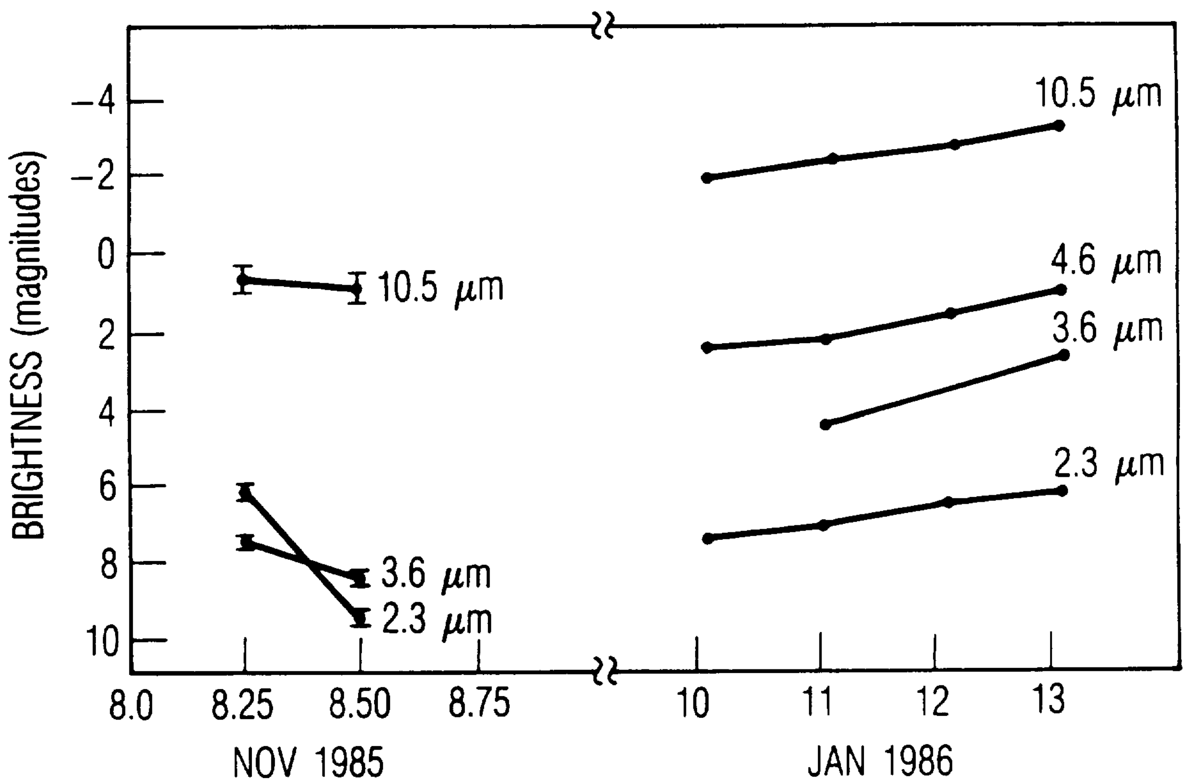

FIGURE 1

COMET HALLEY NOV 8.45, 1985 UT

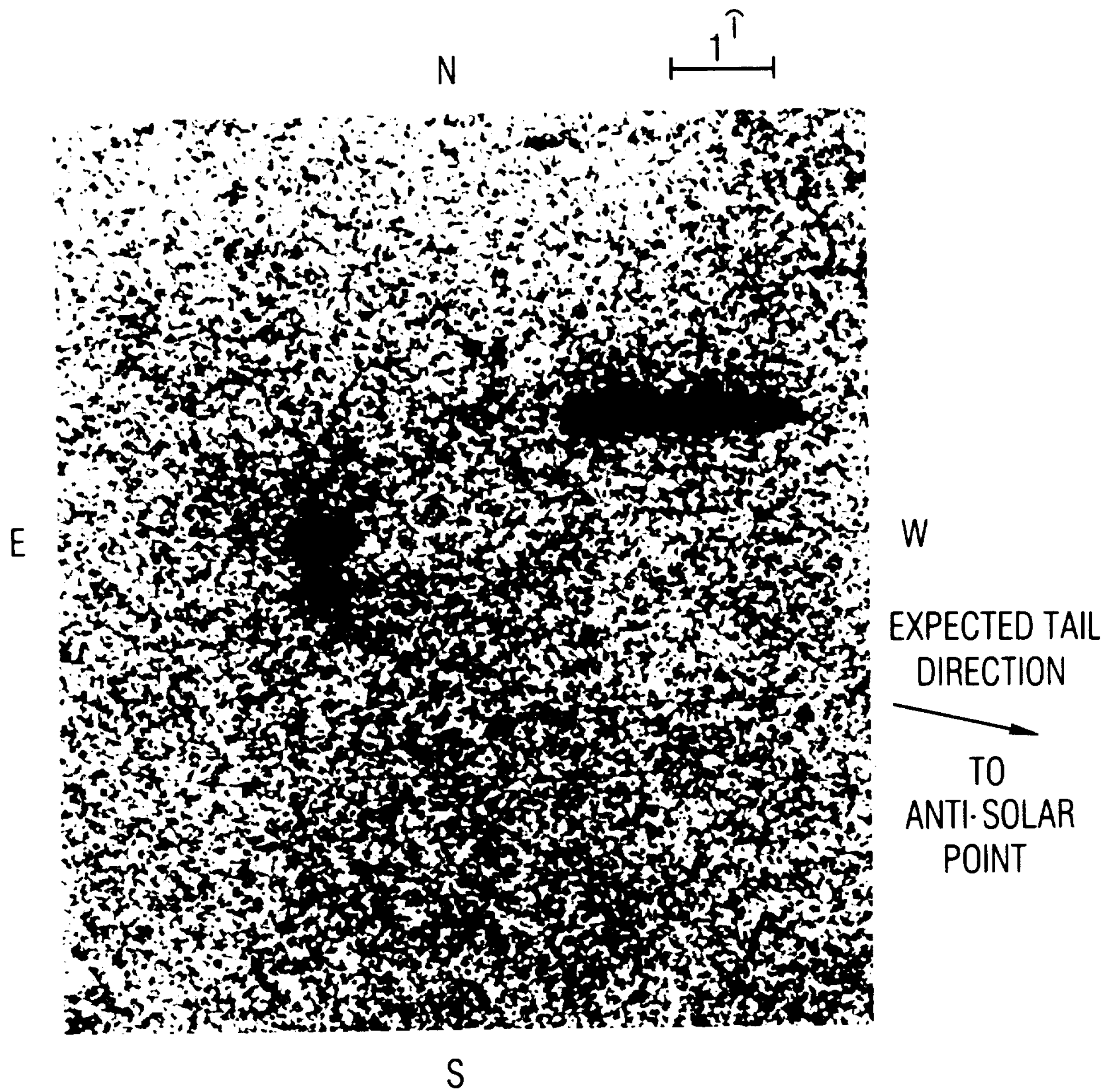

FIGURE 2